MONTHLY PROGRESS REPORT
MONTANA DOT "PERFORMANCE PREDICTION MODELS"
AUGUST 2003

To:	**Susan Sillick, MDT**
	Jon Watson, MDT
Agency:	**Fugro-BRE, Inc.**
MDT Contract No.:	**HWY-30604-DT**
Performance Period:	**July 2003**
Prepared By:	**Brian Killingsworth, PE, Principal Investigator**
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CURRENT MONTH WORK ACTIVITIES AND COMPLETED TASKS

PHASE I

Task 1 – Literature Review

Complete. A draft memorandum, summarizing the models to be considered within this project, was submitted to the Montana DOT (MDT) in October 2001. This memorandum will be updated when the calibration and validation of the 2002 Design Guide distress prediction models are made available.

Task 2 – Review of MT DOT Pavement-Related Data

Complete. However, Fugro-BRE will continue to monitor the LTPP database and update any missing data on the test sections with time.

Task 3 – Establish the Experimental Factorials

Complete.

Task 4 – Develop Work Plan for Monitoring and Testing

Complete. The long-term monitoring plan will be revised after the initial analyses of the data are complete under Tasks 6 and 7.

PHASE II

Task 5 – Presentation of Work Plan to MDT

Complete.

Task 6 – Implement Work Plan – Data Collection

On-going activities. For the 10 sites selected initially (Condon, Deerlodge/Beckhill, Silver City, Roundup, Lavina, Wolf Point, Ft. Belknap, Perma, Geyser, Hammond), all testing has been completed. Of the four Superpave sites for which materials have recently been received, Lothair, and Baum Road have tentatively been selected for inclusion in the testing program. However, testing for these two sites will begin after a review of the results of the calibration exercise currently under way on the initial 10 sites.

Unbound Materials: Base/Subbase and Subgrade (Subcontractor – Fugro-South, Houston, TX): Unbound materials from the 10 sites selected in the experimental factorial (Condon, Deerlodge, Fort Belknap, Geyser, Hammond, Lavina, Perma, Roundup, Silver City, and Wolf Point) have been tested at the Fugro-South laboratory in Houston, Texas. Moisture-density curves at modified compactive effort (AASHTO T180) were derived for each of the 17 materials prior to testing. A repeated load resilient modulus test was performed for each material at optimum moisture content and maximum dry density (modified). The results of these tests have been presented in previous monthly reports.

HMA Cores (Subcontractor – Advanced Asphalt Technologies, Sterling, VA): All testing has been completed. There were two objectives for testing the HMA cores. The first was to obtain data for the Superpave Thermal Fracture analysis. This required low temperature creep and strength data at three temperatures. The second objective was to obtain resilient modulus data to compare with stiffness values obtained from the "Witczak et al." dynamic modulus predictive equation. All test results have been presented in previous reports with the exception of the low temperature indirect strength and strain at failure data which will be available for the next monthly report.

CTB Cores (Subcontractors – Fugro South, Inc. Houston, TX; Texas Transportation Institute, College Station, TX): The objective for testing the CTB cores was to obtain the elastic modulus of the material. However, the test protocol (ASTM C 469 - 94) requires 4 in. diameter by 8 in. length test cylinders to be used as test specimens. Cores more than 8 in. in length have been sent to the Fugro-South laboratory in Houston for coring and testing. Difficulties in obtaining 4" diameter specimens by coring them from the center of the 6 in. diameter cores were still encountered and are due to insufficient binder content. Of the 4 materials sent to Houston (Roundup, Hammond, Wolf Point and Geyser), only two, Wolf Point and Geyser were tested. Although coring was attempted on all materials, the Roundup and Hammond cores could not be reduced to 4 in. diameter specimens. An average modulus value of 996 ksi with a standard deviation of 155 ksi (CV = 0.16) was obtained for Wolf Point. For the weaker Geyser material, an average modulus value of 289 ksi with a standard deviation of 104 ksi (CV = 0.36) was obtained.

CTB cores of less than 8 in. lengths were sent to the Texas Transportation Institute (TTI) laboratory to be tested for indirect tensile strength and strain at failure. The initial plan was to test the specimens in indirect tension, where test specimens are only 1 to 3 in. thick (6 in. diameter). The test specimens were obtained by sawing both ends of the CTB cores that are less than 8 in. long. In order to check the correlation between the elastic modulus measured at the Fugro laboratory and the indirect tensile strength measured at the TTI laboratory, available cores for the Roundup, Hammond, and Wolf Point CTB materials were sent to both labs.

The first few indirect tensile strength tests resulted in serious damage to the instrumentation (LVDT's) mounted on the specimen and an alternative test method was sought. Fugro-BRE suggested the indirect diametral resilient modulus test. However, TTI performed seismic testing on all CTB samples with the exception of Fort Belknap. The Fort Belknap cores were very rough on the sides/ends and were only about 1.5 inches thick which made them unsuitable for testing. Although not included in the initial testing plan, density tests were performed on all CTB materials at the TTI laboratory. The results of the seismic and density tests are presented in Table 1.

Table 1. Results of Seismic Tests (Free-Free Resonant Column Method) and Density Tests

Sample ID	Average Height in	Average Diameter in	Weight grams	Bulk Specific Gravity	Young's Modulus ksi	Young's Modulus Average ksi	Young's Modulus C_v
Wolf Point 1	Tested in IDT	------	----	----------	----	---	------
Wolf Point 2	3.139	5.682	2835.9	2.257	798.6	665.9	0.28
Wolf Point 3	3.108	5.671	2862.3	2.265	533.2		
Hammond 1	3.080	5.665	2434.7	1.997	424.600		
Hammond 2	3.031	5.661	2546.5	2.077	1242.700	863.5	0.47
Hammond 3	3.096	5.658	2581.8	2.067	923.300		
Round Up 1	3.047	5.906	2810.8	2.197	1556.8		
Round Up 2	2.969	5.669	2516.1	2.157	470.5	1033	0.52
Round Up 3	3.102	5.894	2581.8	2.219	1071.7		
Lavina 1	2.928	5.909	2842.6	2.213	2809.800		
Lavina 2	3.073	5.912	3015.8	2.249	1364.100	1132.5	0.71
Lavina 3	3.126	5.906	3049.0	2.217	576.900		
Perma 1	3.475	5.663	2829.9	2.085	317.600		
Perma 2	3.070	5.661	2615.8	2.120	682.700	443.4	0.46
Perma 3	3.579	5.673	3020.7	2.095	329.900		

The modulus values obtained are no doubt highly variable with values of the coefficient of variation in most cases higher than 40%. The Wolf Point material was tested both at TTI using the seismic method and earlier at Fugro South using the elastic modulus test protocol. The three replicates tested at Fugro South had an average modulus of 996 ksi with a coefficient of variation of 15%, as mentioned in the June monthly report. From seismic testing on two replicates, an average of 666 ksi and a coefficient of variation of 28% are obtained at TTI. The disagreement can be explained by variability in the material and by variability due to the test method. However, the extent to which each of these components affects the measured modulus value is unknown and the confidence in the estimated modulus value is rather low. Fugro-BRE will search for more information on seismic testing and how it compares to other methods of testing and possibly ask for diametral resilient modulus test to be performed as a check on the same samples.

<u>Backcalculation of Deflections:</u> The first round of deflection tests have been backcalculated and summarized. In addition, the second round of deflection testing has also been backcalculated utilizing the same pavement structure information as the Round 1 data. Using the backcalculated modulus values, the pavement structure was modeled as a linear elastic layered structure in ELSYM 5 and the states of stress in each layer were estimated under a load of equal magnitude with the one used by the Falling Weight Deflectometer (i.e., 9,000 lbf.). For unbound materials, the resilient modulus at the estimated states of stress was predicted using the 2002 Design Guide stress-dependent model. For the surface layer, the lab-measured resilient modulus values were

used to develop a predictive model for resilient modulus as a function of air voids and temperature. The model was used to predict the lab M_R value at the temperature at which the FWD measurements were taken. Comparisons of the laboratory-derived values with FWD derived values were provided in a previous monthly report. Further analysis of these comparisons will be completed for the Task 7 calibration.

Superpave Supplemental Sites: The project team has received a second shipment of samples from sites constructed with Superpave-designed hot mix and sampled by MDT during the time of construction. The purpose of adding these sections will be to incorporate pavements constructed with current MDT mixture design procedures. A testing plan will be developed once the testing for the initial 10 sites has been completed and calibration results for the initial sites are available.

Field Investigation Report: A field investigation report has been completed by the project team and includes a summary of the distress surveys, field sampling results (cores, borings, and other geotechnical information), FWD deflections (Round 1 only), and longitudinal profiles from each of the supplemental sites.

Supplemental Data: Fugro-BRE contacted Dr. Vince Janoo and obtained a copy of the seasonal data and draft report entitled "Performance of Montana Highway Pavements During Spring Thaw." This data will be used in analyzing the response and performance data that were monitored and obtained from other test sections.

Task 7 – Data Analyses and Calibration of Performance Prediction Models
The objectives of this task are to demonstrate the calibration technique required to develop and maintain the various model calibration coefficients that will be used by the department both now and in the future. As discussed with the MDT, four major distress types were considered in the experimental plan and thus require prediction models and calibration coefficients. These include fatigue cracking (both surface initiated and bottom initiated surface cracks), thermal cracking, rutting or permanent deformation, and ride quality.

The project team is currently awaiting release of the AASHTO 2002 Design Guide information, which is expected by the end of 2003 before attempting any calibration of these models. However, the calibration technique (or the specific steps required to determine calibration coefficients) was demonstrated to MDT utilizing models similar in nature to the AASHTO 2002 Design Guide models. The project team made a presentation to MDT on August 14, including a progress report and findings and an illustration of the calibration exercise for the Silver Spring test section. The PowerPoint file is attached separately as Attachment A.

Calibration Database Development: The initial steps required to populate the calibration and validation database have begun. The first step taken was to verify which LTPP data were missing since the last time it was checked. No significant changes in the available data were found.

Also, the status of the additional LTPP sections outside of, but adjacent to, Montana was verified. Each section was checked for sufficient data so that only those sections with adequate data are being utilized.

In addition, Structured Query Language (SQL) statements were developed for extracting the data required for model calibration from the LTPP IMS. These SQL statements will be provided to MDT so that future calibration efforts utilizing updated LTPP data may be streamlined.

A meeting was held with the database developer that included discussion of the specific requirements for the database. The database developer has restructured the database to make it more user-friendly, which will facilitate MDT using the database for further model calibration after this contract is complete. The draft database schema has been completed, reviewed, and checked, and population of the database has commenced. The draft database schema was included in a previous monthly report.

In response to MDT's request, a list of all database fields and their description was generated and is attached separately as Attachment B in the form of a text file. The file contains not only the name and description of each field but also all other database properties associated with these fields. Due to its size, 160 pages of text, the file will be attached as a soft copy and not a hard copy.

<u>Environmental Data:</u> Montana climatic data will be utilized in the calibration effort. Specifically, the AASHTO 2002 environmental database will be used, which will include information for Montana and surrounding regions. However, it is also recommended that MDT include additional years of environmental data (up to 20 years) to better quantify the expected environmental conditions. The project team is incorporating tables into the calibration database to handle environmental data. This data will include rainfall and temperature information as well as in-situ moisture information for the appropriate environmental zones delineated in the State.

<u>Traffic Data:</u> A review of all the LTPP traffic tables has been initiated. The completeness of the data will be documented and the need for additional traffic information will be assessed. Recommendations for the required traffic information have already been discussed among the project team, Mr. Von Quintus, and Dr. Mark Hallenbeck (who will continue gathering, reviewing, and assessing this data, especially in light of the initial calibration effort currently underway).

Task 8 – Final Report and Presentation of Results
No activity.

PROBLEMS / RECOMMENDED SOLUTIONS

No problems were encountered during last month and none are anticipated next month.

NEXT MONTH'S WORK PLAN

The activities planned for next month are listed below:

- Coordinate with MDT personnel on an as-needed basis.
- Continue analysis of all data collected at the LTPP and non-LTPP test sections.
- Analyze CTB test data and test procedure and decide if further testing is needed.
- Continue with the calibration for the 10 non-LTPP sites and all LTPP sites.

FINANCIAL STATUS

The Financial Summary I table shows the estimated expenses incurred during the reporting period.

The Financial Summary II table provides the total project expenditures by the Montana and FHWA fiscal years in comparison to the allocated funds for each fiscal year.

The Financial Summary III chart illustrates total expenditures by month for the project.

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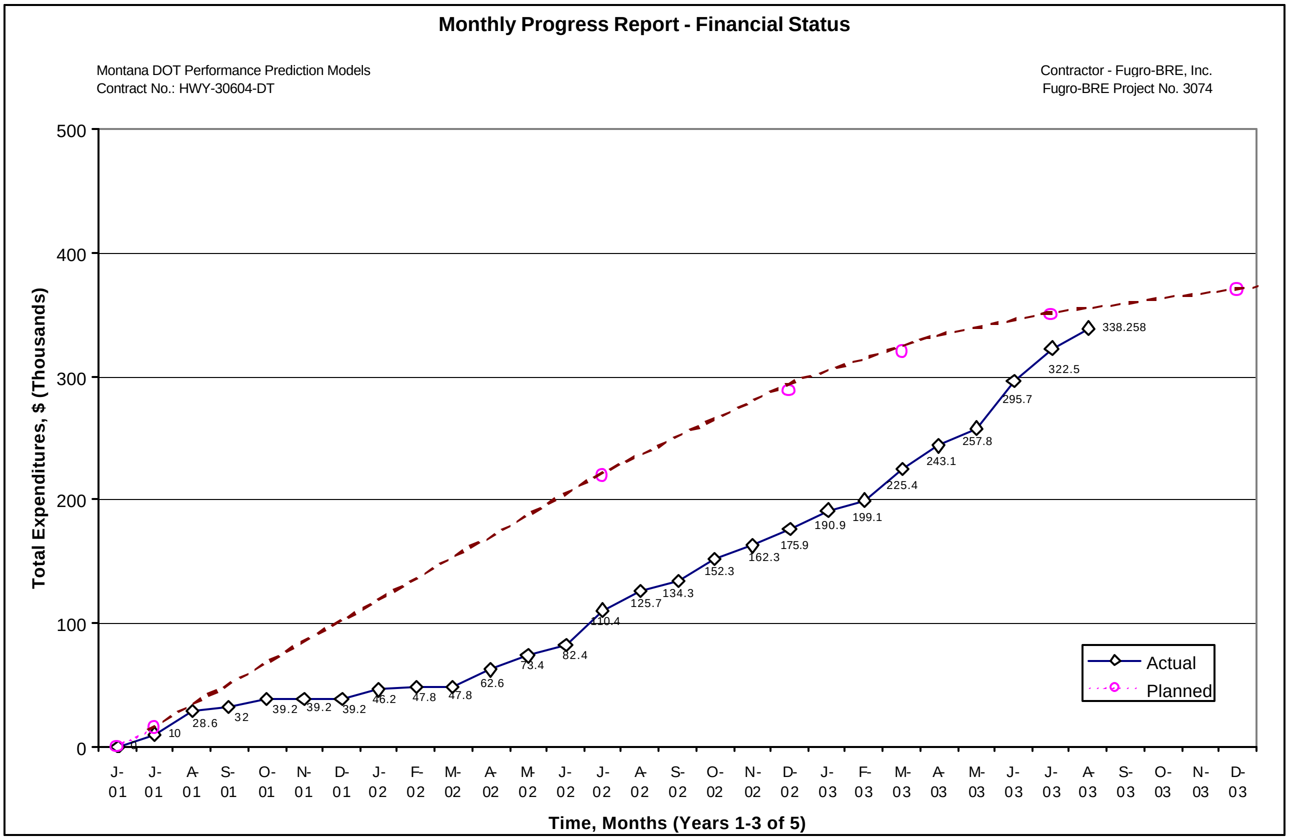
Financial Summary I
Estimated Expenses for Reporting Period: Fugro-BRE

Cost Element	Cumulative Cost Jun 2001 - Jul 2003, $	Current Expenditures Aug 2003, $	Cumulative Costs Jun 2001 - Aug 2003, $
Direct Labor	69,705	5,142	74,847
Overhead	99,678	7,353	107,031
Consultants/Subcontractors	4,050	0	4,050
ERES/ARA	15,085	0	15,085
Parsons-Brinkerhoff	12,093	0	12,093
SME	523	0	523
Dr. Matthew Witczak	0	0	0
Dr. Mark Hallenbeck	3,129	0	3,129
Travel	12,955	0	12,955
Testing	71,916	78	71,994
Other Direct Costs	4,090	1,710	5,800
Fee	29,322	1,428	30,750
TOTAL	322,548	15,711	338,259

Financial Summary II
Total Expenditures by Fiscal Year: Montana and FHWA

MONTANA DOT FISCAL YEAR			**FHWA FISCAL YEAR**		
Allocated Funds Cumulative, $		**Fiscal Year**	**Allocated Funds Cumulative, $**	**Fiscal Year**	**Allocated Funds Cumulative, $**
6/1/2000-6/30/**2001**	15,000	*0	6/1/2000-9/30/**2001**	65,000	31,996
7/1/2001-6/30/**2002**	218,969	82,420	10/1/2001-9/30/**2002**	258,969	102,303
7/1/2002-6/30/**2003**	348,969	213,291	10/1/2002-9/30/**2003**	358,969	203,959
7/1/2003-6/30/**2004**	388,969	42,547	10/1/2003-9/30/**2004**	398,969	---
7/1/2004-6/30/**2005**	428,969	---	10/1/2004-9/30/**2005**	438,969	---
7/1/2005-6/30/**2006**	498,969	---	10/1/2005-9/30/**2006**	498,969	---
TOTAL	498,969	338,258		498,969	338,258

*June 2001 expenditures were combined with July 2001 expenditures.



Financial Summary III:
Total Expenditures By Month